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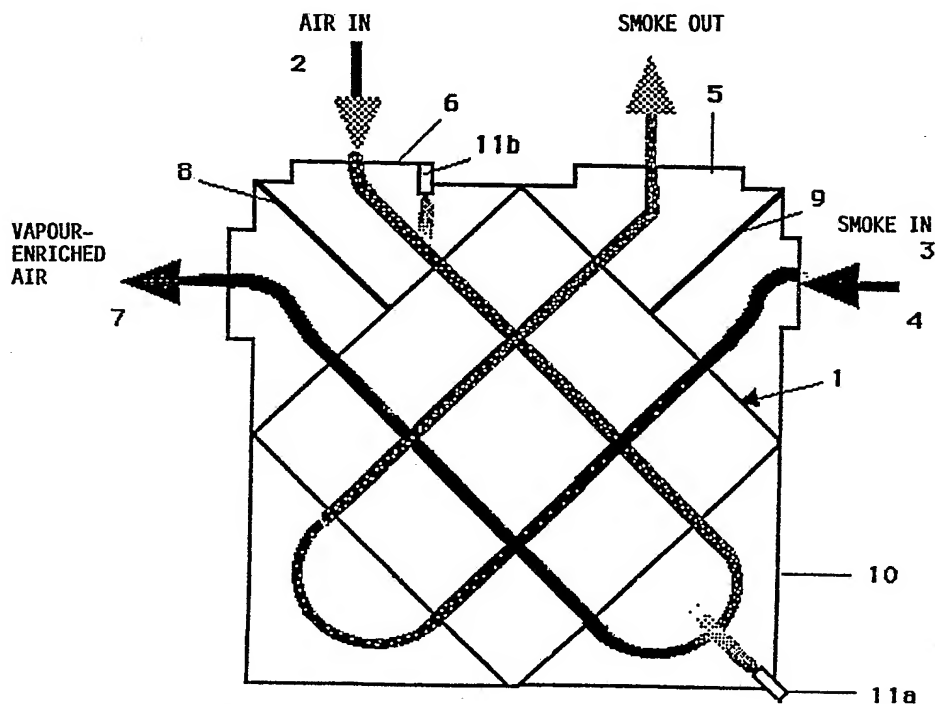
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(57) Abstract

The present invention relates to an apparatus for vapour enrichment of air, in which latent energy from flue gases is transmitted to air. The invention is characterised in that the air and the flue gases pass through a heat exchanger, preferably a transverse or cross-flow heat exchanger, without being mixed, whereby finely dispersed water and/or alcohol is sprayed into the air in the form of mist and vapourised by the heat released during the process of water-vapour condensation in the flue gases.

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## PROCESS AND ARRANGEMENT FOR VAPOUR ENRICHMENT OF AIR

In general the present invention relates to a process and an arrangement for considerably reducing the negative effect of flue gases on the environment. In particular the invention relates to an apparatus by which combustion air can be efficiently enriched with vapour, whereby the energy for vapour enrichment is derived from the energy released in the process of flue-gas condensation.

Since time immemorial combustion gases have exerted an influence on the environment. Whereas in earlier times the gases were in the main due only to volcanic eruptions and forest fires, this effect as brought about by combustion gases due to human activities has, since the industrial revolution, become an increasingly serious problem and the subject of greater attention. Awareness of the environmental problem resulting from combustion dates back to the 17th century, when regulations were introduced in England to restrict coal firing in certain densely populated areas.

Polluted flue gases exert a negative effect on the environment inasmuch as they contain solid, liquid and gaseous impurities. Apart from the fact that the efficiency of a furnace can be increased by an order of magnitude of 20 - 25%, the discharges of dust and dust-borne impurities can be reduced by up to 90 - 95%, merely by condensation of the flue gases, while other gaseous and water-soluble impurities are separated from the flue gases and transferred to the condensate. Owing to the presence of chlorinous impurities in certain fuels the condensate is frequently highly acidic and can be subjected to further purification if necessary. This makes great demands on the structural material in the condensation plant and also on the system for processing the condensate. If use is made of biomass fuel the conditions are such as to give rise to a high pH-value, which may be higher than 8, and this can cause problems in the form of deposits and operational faults. Problems have also arisen due to

icing-up in the winter, inasmuch as hitherto it has not been possible to cool the flue gases sufficiently during condensation, so that the remaining high contents of water vapour in the saturated flue gases are precipitated if further cooling takes place.

A known method for achieving more efficient cooling of the flue gases and hence a further recycling of energy from the flue gases involves the use of a heat pump. With this method the cooling medium in the evaporator pertaining to the heat pump is vapourised by the heat released as the flue gases condense in the heat-pump evaporator. It is technically possible to cool the flue gases to temperatures below 0°C.

It is as such known how to enrich combustion air with vapour, i.e. to raise its dew point by making use of the energy released in the process of flue-gas condensation. This makes it possible to transform low-grade latent energy in the flue gases into latent energy in the combustion air, and said low-grade energy can be recycled at a higher temperature level by condensing the flue gases.

Nowadays efficient combustion is most commonly achieved at high combustion temperatures which give rise to high concentrations of thermal nitrogen oxides in the flue gases. It is difficult to process and neutralise these nitrogen oxides in an efficient manner, which is the reason why they are nowadays discharged and exert a negative effect on the environment. Efficient vapour enrichment of the combustion air causes the partial pressure of the water vapour contained in the combustion air to reduce the partial pressure of the oxygen, i.e. the oxygen content in the combustion air can be reduced to about 15 - 17%, thus markedly lowering the combustion temperature to levels at which the proportion of thermal nitrogen oxides is reduced.

The main object of the present invention consists in providing a method enabling, in a particularly efficient manner, vapour enrichment of air, preferably combustion air, by making use of the energy released in the process of flue-gas condensation, thus enabling vapour enrichment to about 80°C, in which case each m<sup>3</sup> of combustion air contains latent energy in the form of 290 g water vapour.

A further object of the present invention is to provide an apparatus which is cheap to manufacture, easy and simple to maintain and possibly to clean, and which can readily be installed in existing combustion plant.

Yet another object of the invention consists in providing an apparatus enabling energy exchange between flue gases and combustion air without causing any substantial restriction of the gas and air flows.

The objects listed above are achieved by the process and the arrangement being designed with the characteristics stated in the claims.

By keeping air and flue gases separate as they pass over the surfaces of the heat exchanger and by spraying water and possibly also alcohol into the air in finely dispersed form (as a mist) it becomes possible to achieve efficient transfer of the latent energy from the flue gases to the air while vapourising the water sprayed into the air.

Inasmuch as the air is passed through several flow passages between a pair of plates in a plate heat exchanger, said passages being separate from one another and located next to one another, the distance over which vapour enrichment can take place is relatively long. The water is sprayed in at at least one but preferably several points along the air flow path in the heat exchanger in order to reduce the risk of excess water in the form of a thickened film of water

settling on the surfaces of the heat exchanger. It is therefore of great importance to facilitate the transfer of a sufficient amount of heat from the flue gas condensation in order to vapourise injected mist. To conclude the vapour enrichment of the air, use may advantageously be made of alcohol, i.e. by using alcohol it is possible to reduce the temperature of the flue gases efficiently to a level considerably below that of the environment. If air is used by way of combustion air in a furnace, the combustion energy in the vapourised alcohol is also recycled.

By at least passing the air through the first group of flow ducts arranged in such a way as to pass the air into a space outside the plates with a view to turning it around there and passing it back through the other group of flow ducts located adjacent to and parallel to the first flow ducts between the same pair of heat exchanger plates, it becomes possible, at several points along the flow path of the air, to introduce into the air finely dispersed water (alcohol) in the form of mist. If the cross-section of the heat exchanger is rectangular, one side being considerably longer than the other side, it becomes possible to pass the air solely outside the boundary edges of the heat exchanger, i.e. the flue gases pass along the longitudinal side of the heat exchanger whereas the air passes across the longitudinal side of the heat exchanger. In this case it becomes possible to achieve an advantageously high and constant  $t$ -ratio over the surfaces of the heat exchanger for optimising the transfer of energy between flue gas and air.

By creating a turbulence within the heat exchanger the efficiency of the heat exchanger is increased. It is possible in this connection to allow different degrees of turbulence to occur both on the flue-gas side and on the air side.

The water sprayed into the combustion air in the form of mist is advantageously filtered and purified flue-gas condensate. Depending on the type of fuel and its moisture content, it is, according to the invention, possible in certain cases to recirculate the condensate entirely to the combustion air.

The invention will now be described with reference to the embodiment shown in the attached drawing, where

Fig. 1 is a perspective view of a type of cross-flow heat exchanger which with the present invention can be used advantageously, whereby the different flows are indicated by arrows,

Fig. 2 shows a heat exchanger according to Fig. 1 in schematic side-view with a first embodiment of the invention,

Fig. 3 shows a heat exchanger according to Fig. 1 in schematic side-view with a second embodiment of the invention, and

Fig. 4 shows a cross-flow heat exchanger of rectangular cross-section with a third embodiment of the invention.

Fig. 1 shows a heat exchanger 1 of cross-flow type, said heat exchanger being already known. Arrow 2 indicates air in the process of vapour enrichment, whereas arrow 3 indicates smoke discharging energy to the heat exchanger during condensation. The heat exchanger consists of several stacked profiled plates a and b, with parallel flow ducts being formed between said profiled plates. The profiles are so arranged as to ensure that the flow ducts on either side of a plate a, b pass one another at right angles. Inasmuch as they are profiled, the plates also constitute spacing devices at the same time.

Fig. 2 shows heat exchanger 1 with air inlet 6 and air outlet 7 as well as smoke inlet 4 and smoke outlet 5. Between air inlet 6 and air outlet 7 there is a first separating screen 8, whereas a second separating screen 9 is arranged between smoke inlet 6 and smoke outlet 5. The heat exchanger unit and screens are located within an insulated casing 10. Water-spray devices 11 are shown in part at air inlet 6 (11b) and in part (11a) at air-reversing screening devices (not shown).

Fig 3 shows a variation of the embodiment according to Fig. 2. whereby further screening devices 12 and 13 are arranged so as to bring about several opportunities for finely dispersed water to be supplied to the air. Otherwise said embodiment corresponds to the embodiment shown in Fig. 2. Thus screening devices 8' and 9' are in this case divided into two parts, whereas additional screening devices 12 and 13 are provided so as to constitute flow ducts for air and flue gas. With this embodiment three spray devices 11' are provided. It is of course also possible to arrange a spraying device directly connected with the air inlet, as is the case with the embodiment shown in Fig. 2.

Lastly, Fig. 4 shows an embodiment of rectangular cross-section over cross-flow heat exchanger 1', whereby the flue gases 3' pass straight through the heat exchanger, whereas air flow 2' passes several times in the direction from the flue-gas outlet (the right-hand end in the Figure) to the flue-gas inlet (the left-hand end in the Figure). This makes it possible to arrange several spraying devices 11" for injecting water into the air while said air passes outside heat exchanger 1' itself.

The invention is not restricted to the aforementioned embodiments, modifications being possible within the scope of the claims stated below.

## CLAIMS

1. Process for vapour enrichment of air in which latent energy from flue gases is transferred to air, characterised in that the air and the flue gases pass through a heat exchanger, preferably a transverse or cross-flow heat exchanger, without being mixed, whereby finely dispersed water and/or alcohol is sprayed into the air in the form of mist and vapourised by the heat released as the water vapour condenses in the flue gases.

2. Process according to Claim 1, characterised in that at least the air is conducted through several first groups of flow passages in a plate heat exchanger, said flow passages being separate from one another and located next to one another, whereby spraying of water into the air in the form of mist is effected at at least one point along the flow path of the air in the heat exchanger.

3. Process according to Claim 2, characterised in that at least the air is conducted through the first group of flow ducts which are so arranged that the air is caused to pass out into a space outside the plates in order to turn around there and flow back through second flow ducts in the first group located next to the first flow ducts and parallel thereto between the same pair of heat exchanger plates.

4. Process according to one of the preceding Claims, characterised in that, as a final stage in the vapour enrichment of air, alcohol is sprayed into the air in the form of mist, whereby condensation of the water vapour in the flue gases can take place down to temperatures considerably lower than the temperature of the environment.

5. Process according to one of the preceding Claims, whereby the air is combustion air, characterised in that the water sprayed into the combustion air is filtered and purified condensate from the flue gases.

6. Arrangement for vapour enrichment of air, in which process latent energy from flue gases is transferred to air, and for carrying out the process according to Claim 1, characterised by a heat exchanger, preferably a cross-flow heat exchanger, which is equipped with flow ducts both for air and flue gases, said flow ducts being located next to one another and hermetically separated, whereby spraying devices for spraying in liquid in the form of mist are arranged within or in connection with the flow ducts for air.

7. Arrangement according to Claim 6, characterised in that the entire length of the flow duct in the heat exchanger for at least the air exceeds the width of the heat exchanger plates.

8. Arrangement according to Claim 7, characterised in that air and possibly gas-turning screening devices are arranged outside the sides of the heat exchanger.

9. Arrangement according to Claim 8, characterised in that the spraying devices are arranged in connection with the air-turning screening devices, i.e. outside the sides of the heat exchanger.

10. Arrangement according to Claim 8 or 9, characterised in that the heat exchanger and the air and gas-turning screening devices respectively are located in a chamber of square or rectangular cross-section, whereby the gas and air-flow parts of the chamber are in the main hermetically separated and where inlet and outlet openings are arranged for both gas and air.

Fig. 1

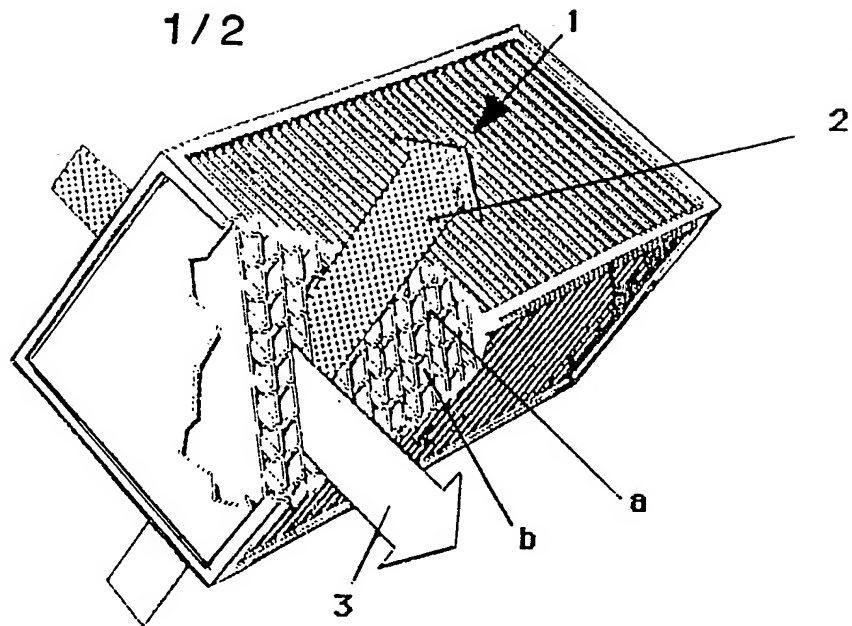
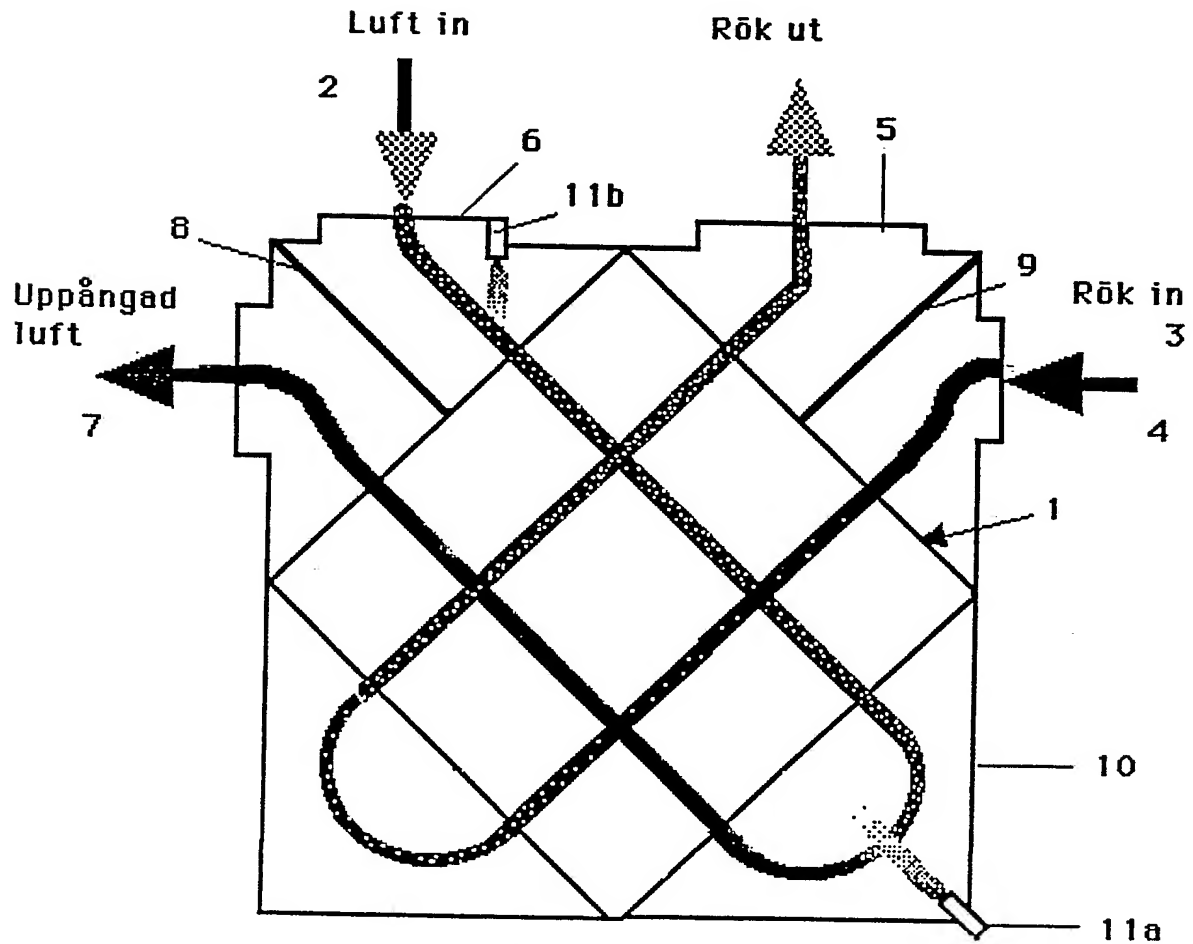


Fig. 2



SUBSTITUTE SHEET

Fig. 3

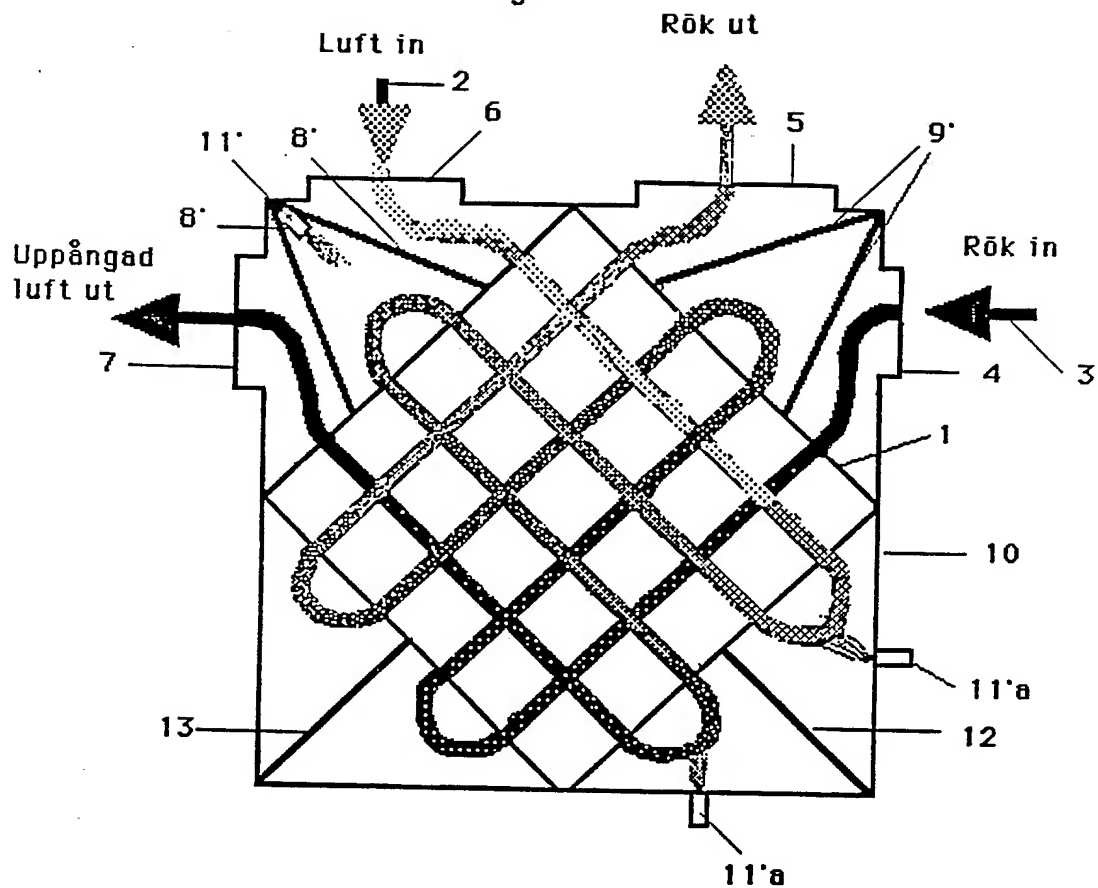
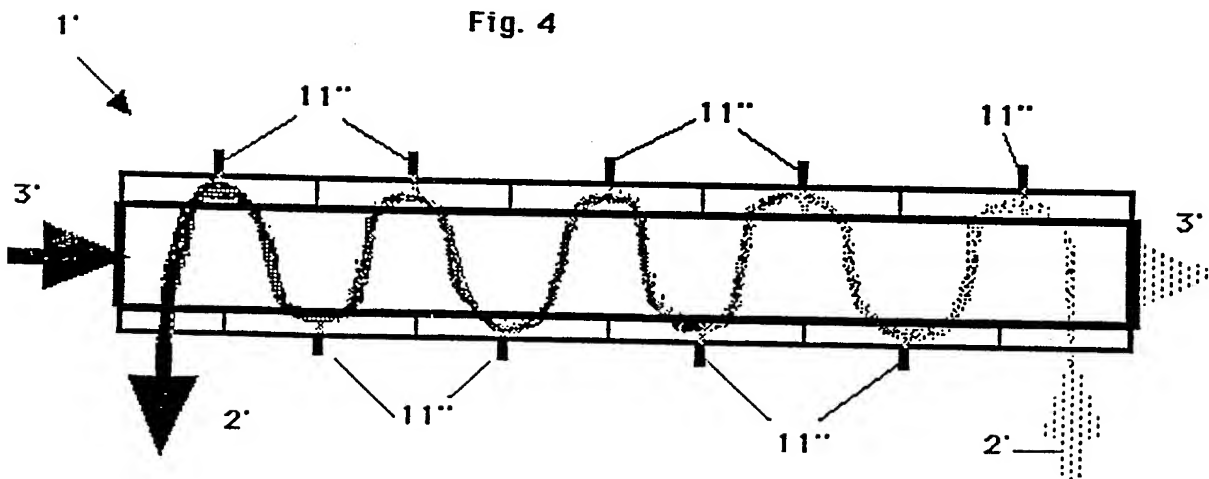


Fig. 4



## Key to drawings

Luft in	Air in
Rök ut	smoke out
Rök in	smoke in
Uppångad luft	vapour-enriched air
Uppångad luft ut	vapour-enriched air out

## INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE 93/00228

## A. CLASSIFICATION OF SUBJECT MATTER

IPC5: B01D 1/16, B01D 5/00, F23J 15/00

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC5: B01D, F23J

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4287938 (SVEN G.R. LAGERQUIST ET AL), 8 Sept 1981 (08.09.81), column 1, line 18 - line 24; column 2, line 12 - line 17, figure 1 --	1
Y	US, A, 4786301 (BARRY V. RHODES), 22 November 1988 (22.11.88), column 5, line 11 - line 36 --	1
A	US, A, 4452180 (KAMAL-ELDIN HASSAN), 5 June 1984 (05.06.84), claim 1 -- -----	1,6

☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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# INTERNATIONAL SEARCH REPORT

Information on patent family members

28/05/93

International application No.

PCT/SE 93/00228

Patent document cited in search report		Publication date	Patent family member(s)	Publication date	
US-A-	4287938	08/09/81	DE-A-	2936684	03/04/80
			GB-A-	2031572	23/04/80
			JP-A-	55041398	24/03/80
			SE-A-	7809801	15/03/80
-----					
US-A-	4786301	22/11/88	NONE		
-----					
US-A-	4452180	05/06/84	NONE		
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**ABSTRACT:**

CHG DATE=19990617 STATUS=O>The present invention relates to an apparatus for vapour enrichment of air, in which latent energy from flue gases is transmitted to air. The invention is characterised in that the air and the flue gases pass through a heat exchanger, preferably a transverse or cross-flow heat exchanger, without being mixed, whereby finely dispersed water and/or alcohol is sprayed into the air in the form of mist and vapourised by the heat released during the process of water-vapour condensation in the flue gases.